Applying Ultrasonic Technology

Critical Factors to Consider When Selecting a Transducer

Designers of ultrasonic systems have their choice of frequency, housing design and mounting options when utilizing ultrasonic transducers. Balancing the trade-offs between transducer performance, acoustic beam characteristics and incorporated electronics is a critical step in the system design process. The transducer's performance can be affected by the propagating media, the environmental conditions and the electronics themselves. Several parameters need to be considered when selecting a transducer appropriate to the application. The purpose of this overview is to outline key factors to be considered.

Maximum Sensing Range

Many elements can influence the maximum sensing range of a transducer. As a result, several factors should be considered beyond the transducer itself when designing an ultrasonic system. These factors can include atmospheric conditions, drive and receive electronics, and signal processing. Some of these are discussed below.

Temperature and Humidity

Changes in temperature cause a change in sound speed of air, as well as the materials of any ultrasonic transducer. Operation at significantly higher or lower temperatures than the transducers are optimized for results in "detuning" of the acoustic matching layer of the transducer and shifting of the resonant frequency, resulting in degraded performance. Resonant frequency shifts approximately -0.8% per 10°C (0.8% per -10°C). The reduced sensitivity is tolerable for most applications, but for applications with a wide temperature range, correction may be necessary.

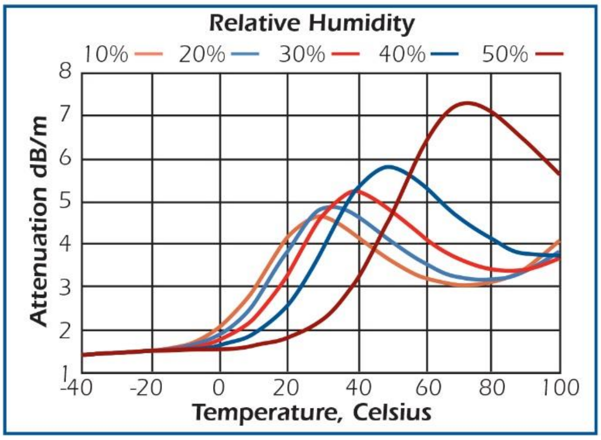

Figure 1: Signal attenuation in air at 1 atmosphere at 100

$$S.O.S. = 20.1 * \sqrt{T_c + 273}$$

where T_c = Temperature in degrees Celsius

Figure 2: Speed of sound in air

The characteristics of air are dramatically changed by environmental conditions. Shown in Figure 1, signal attenuation is a function of temperature, humidity, frequency, and air pressure. The speed of sound is mainly a function of temperature, shown in Figure 2. Humidity plays a minor role in sound speed, accounting for less than 0.6% change in speed for the temperature range shown. Some transducers offer optional internal thermistors for speed of sound compensation. External temperature sensors can be used for a more accurate calibration over a longer range.

Air Currents and Atmospheric Influences

Maximum measurement ranges are affected by air turbulence, which may deflect or deteriorate sound waves and reduce echo signal. Air currents tend to carry sound downwind; large currents can deflect sound enough to miss the intended target. Large sudden temperature differentials will reflect sound.

Light snow or rain in the sound path will attenuate the sound waves thereby reducing range. Lower frequency transducers emit a longer wavelength so the degrading effect of snow and rain is not as significant as it is for high frequencies.

Interference
(Electrical and Acoustical)

Air-ranging ultrasonic transducers that could be susceptible to RFI and EMI might include standard internal shielding. Additional shielding may be required in certain environments.

High-pressure air nozzles, such as blow off guns, create large amounts of ultrasonic noise. This noise can be very wide band and difficult to filter out. Installations near air nozzles should be avoided.

Transducers mounted to vibrating equipment can receive mechanically coupled interference. If the transducer will be subject to vibration, a very compliant mounting material should be considered to minimize vibration transmission to the transducer.

Target Strength

Hard, smooth and flat targets mounted orthogonally to the transmitted beam return the strongest signals and hence will be detectable at longer ranges. Examples of these mediums are liquid, glass, or metal. If the beam is not orthogonal, it will be reflected off at the angle of incidence and not be received by the transducer. For example, the signal for a transducer with a 10° beam angle will be degraded by 3 dB if the target is misaligned by 2.5°.

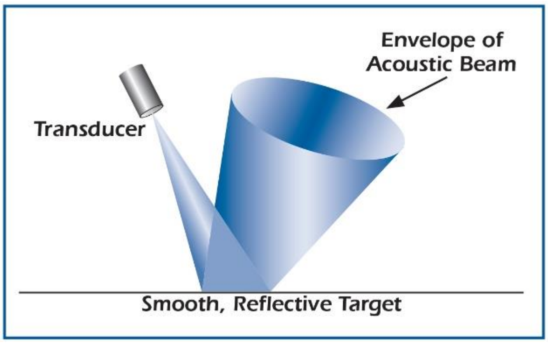

Figure 3: Sound reflective at the angle of

If a surface is rough and irregular, the signal returned is varied in amplitude due to the scattering of sound. This type of target has the disadvantage that the return signal is smaller but has the advantage that the target’s alignment is less critical. Further, different materials have widely different abilities to reflect sound. For example, surfaces such as fabric and foam have the lowest reflectivity resulting in low amplitude echoes thereby significantly reducing the effective range of the transducer.

Beam Angle

A transducer transmits energy in a beam pattern. Most of the energy is concentrated in the main lobe which defines the beam width. Energy outside the main lobe is concentrated in sidelobes. Sidelobes can disguise the true location of targets by generating phantom echoes. No transducer is ever completely free of sidelobes but most air-ranging ultrasonic transducers are designed with low side lobe levels at least 17 dB below the main lobe.

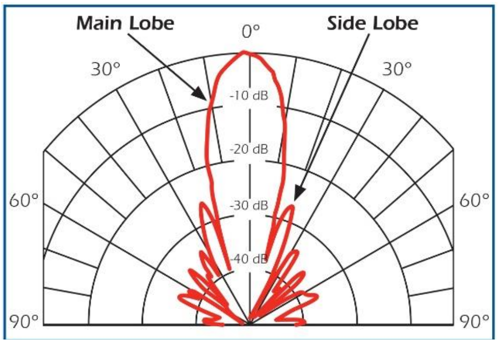

Figure 4: Typical beam pattern

Wide beam angles reduce the sensing range of the transducer and provide less target discrimination when compared to narrow beam models. Wide beams spread acoustic energy over a greater volume and hence less acoustic energy is reflected from potential targets than from a narrower, more concentrated beam. When compared to wide beams, narrow beam angles tend to have greater variations in echo amplitude with irregular surfaces such as a wavy fluid target.

Minimum Sensing Range

The distance from the active surface of a transducer to the minimum sensing range is often referred to as the Blanking Zone. Within this zone no echo signals can be received. Ideally, this distance would be zero.

The blanking zone is caused by a phenomenon called ringing. Ringing is the continued vibration of the piezoelectric transducer element beyond the electrical excitation pulse. Due to the nature of piezoelectric ceramics and the constraints of transducer design, there will always be some amount of ring time. This time is necessary to dissipate mechanical and electrical energy after excitation ceases.

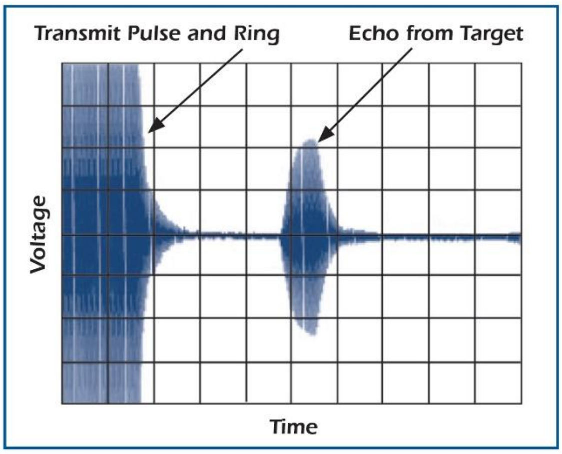

Figure 5: Transmit ring example

The extent to which a transducer rings depends on its design. The amount of ring will also vary slightly from transducer to transducer of the same design due to manufacturing tolerances.

The type of electrical pulse used to drive the transducers can have a profound effect on the amount of ring. Some characterizations of ring time are based on a tone burst drive (i.e., typically ten cycles at best operating frequency). A transducer has many modes of vibration - some are strongly coupled to air and some are not. When designing a system, the objective is to drive the transducer at a frequency strongly coupled to air and avoid exciting extraneous resonances. Hence, the use of a tone burst (narrow bandwidth) is beneficial. In contrast, the use of a wide-band transmit scheme can excite undesirable vibration modes. For example, “impulse” drive electronics in which a high-voltage, short duration burst of energy is applied to the transducer excites virtually all vibration modes. Modes of vibration other than the desired resonance often dissipate their energy more slowly. When these undesirable frequencies are stimulated, ring time increases.

All air transducers have a secondary resonance adjacent in frequency to the desired resonance. This secondary resonance is a direct result of the use of an acoustic matching layer to better couple the piezoelectric ceramic element to air. Please refer to Figure 6. The secondary resonance is more weakly coupled to air and also exhibits greater ringing than the desired resonance.

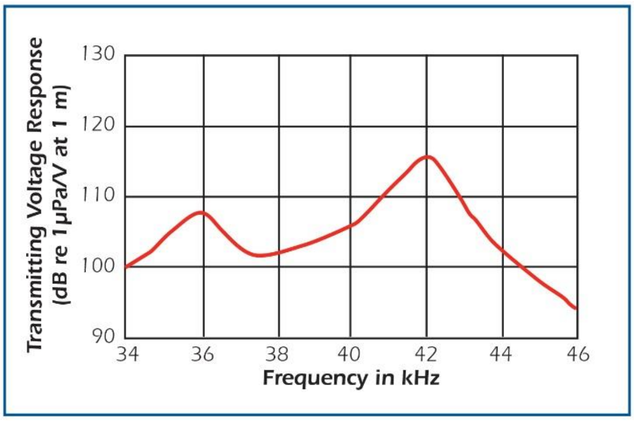

Figure 6: Transmitting response showing adjacent

Mounting

Since the transducer is an electromechanical device, some vibrational energy is transmitted to the transducer housing. A rigid mount of the transducer can accentuate these vibrations and cause an increase in ring time. A compliant mount typically has the least effect on transducer performance. Transducers should not be forced into a press fit mounting location.

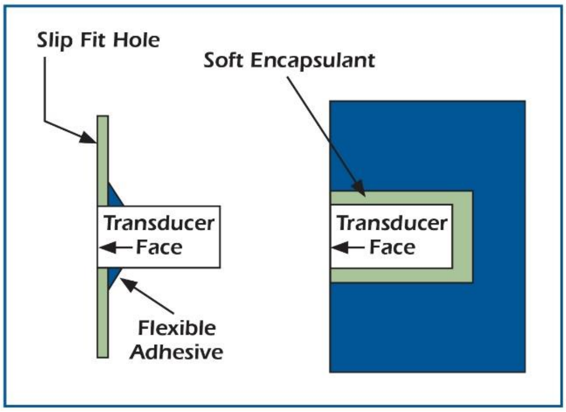

Figure 7: Mounting examples

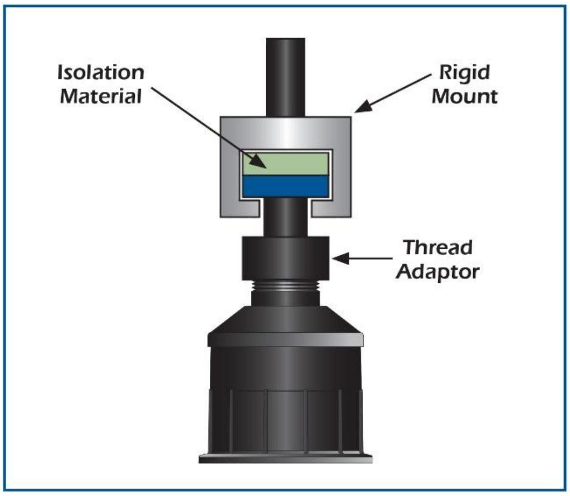

Figure 8: Isolation bushing example

Mounting the transducer on the outside diameter of the housing could cause an increase in ring time. If additional isolation is necessary, the use of an isolation bushing (as shown) is recommended.

About AIRMAR Technology Corporation

AIRMAR® Technology Corporation, an Amphenol® company, is a world-leading designer, manufacturer and supplier of high-performance ultrasonic industrial, marine and survey transducers, and ultrasonic WeatherStation® multisensors.

Airmar produces the most reliable, high-quality non-contact ultrasonic air transducers for use in today's challenging commercial and industrial applications. Our Airducer® air-ranging transducers are critical components in the development of a myriad of measurement systems in fields that require liquid or solid levels, flow control, automation control, proximity sensing, obstacle avoidance, distance measurement and process control.

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